U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

# TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

A1
1587

U.S. APPLICATION NO. (IF K...
09/830540

| INTERNATIONAL APPLICATION NO. | INTERNATIONAL FILING DATE | PRIORITY DATE CLAIMED |
|---|---|---|
| **PCT/DE 99/03329** | **OCTOBER 16, 1999** | **OCTOBER 30, 1998** |

TITLE OF INVENTION
**METHOD FOR TRANSMITTING SIGNALS BETWEEN A FIRST AND A SECOND RADION STATION, AND RADIO STATION**

APPLICANT(S) FOR DO/EO/US
**Frank KOWALEWSKI**

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ A copy of the International Search Report (PCT/ISA/210).
8. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

**Items 13 to 18 below concern document(s) or information included:**

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31
15. ☒ A **FIRST** preliminary amendment.
    A **SECOND** or **SUBSEQUENT** preliminary amendment.
16. ☐ A substitute specification.
17. ☐ A change of power of attorney and/or address letter.
18. ☒ Certificate of Mailing by Express Mail
19. ☐ Other items or information:

ET364058

UNITED STATES PATENT AND TRADEMARK OFFICE

Examiner:

Group:

Attorney Docket # 1567

Applicant(s) : KOWALEWSKI, F.

Serial No. :

Filed : Simultaneously

For : METHOD FOR TRANSMITTING SIGNALS BETWEEN A FIRST AND SECOND RADIO STATION, AND A RADIO STATION

JC18 Rec'd PCT/PTO

09/

SIMULTANEOUS AMENDMENT

April 26, 2001

Honorable Commissioner of Patents and Trademarks
Washington, D.C. 20231

SIRS:

*Simultaneously* with filing of the above identified *application* please amend the same as follows:

In the Claims:

Cancel all claims without prejudice.

Substitute the claims attached hereto.

REMARKS:

This Amendment is submitted simultaneously with filing of the above identified *application*.

With the present Amendment applicant has amended the claims so as to eliminate their multiple dependency.

Consideration and allowance of the present application is most respectfully requested.

Respectfully submitted,

Michael J. Striker
Attorney for Applicant(s)
Reg. No. 27233

Claims

1. A method for transmitting signals between a first radio station (1) and a second radio station (2), in which a pre-equalization of the signals to be transmitted is done in a modulator (4) of the first radio station (1), characterized in that the pre-equalized signals are transmitted from the first radio station (1) to the second radio station (2) via a plurality of radio channels (20, 25).

2. The method of claim 1, characterized in that one pre-equalized signal at a time is transmitted by a plurality of antennas (50, 55) of the first radio station (1) and via a respective radio channel (20, 25) to the second radio station (2), wherein for each radio channel (20, 25) an estimate of an impulse response is ascertained in the first radio station (1), and a pre-equalization of the signal to be broadcast from the applicable antenna (50, 55) is performed as a function of the estimate of the impulse responses of the radio channels (20, 25).

3. The method of claim 2, characterized in that a reference signal is transmitted from an antenna (60) of the second radio station (2) to the first radio station (1) via the radio channels (20, 25), and that the estimate of the impulse response of the respective radio channel (20, 25) is derived from a reception of the reference signal in the first radio station (1) via the respective radio channel (20, 25).

4. The method of claim 1, [2 or 3,] characterized in that a pre-equalized signal broadcast by the first radio station (1) is received by a plurality of antennas (60, 65) of the second

radio station (2), each via a respective radio channel (20, 25), and in the first radio station (1) an estimate of a total impulse response of all the radio channels (20, 25) is ascertained, and a pre-equalization of the signal to be broadcast by the first radio station (1) is performed as a function of the estimate of the total impulse response, and that the received signals formed by the antennas (60, 65) of the second radio station (2) are combined linearly and are then delivered to a demodulation.

5. The method of claim 4, characterized in that one reference signal is transmitted from the antennas (60, 65) of the second radio station (2) to the first radio station (1) via the associated radio channel (20, 25), and that the estimate of the total impulse response is derived from a superimposed reception of the reference signals in the first radio station (1).

6. The method of claim 5, characterized in that each reference signal is multiplied by a coefficient as a function of the radio channel (20, 25) used for its transmission, and that in the linear combination of the signals received by the antennas (60, 65) of the second radio station (2), each received signal is multiplied by the coefficient of the radio channel (20, 25) used for its transmission.

7. The method of [one of the foregoing claims] claim 1, characterized in that via further radio channels, signals are transmitted between the first radio station (1) or the second radio station (2) and further radio stations (3), wherein the data from different radio stations transmitted with the signals is expanded with different codes, and that the pre- equalization is performed in the modulator (4) of the first radio station (1) as a function of all the different codes and of the transmission

properties of all the radio channels.

8. The method of claim 7, characterized in that the transmission properties of the radio channels are ascertained from data transmissions of the second radio station (2) and the further radio stations (3) to the first radio station (1).

9. A radio station (1) having a modulator (4), in which a pre-equalization of signals to be transmitted is effected in the modulator (4), characterized in that at least two antennas (50, 55) are provided, from which a broadcasting of the pre-equalized signals is effected, via a respective radio channel (20, 25), to a further radio station (2).

10. The radio station (1) of claim 9, characterized in that at least one channel estimator (11, 12) is provided, which for each radio channel (20, 25) ascertains an estimate of its impulse response, and that the pre-equalization of the signal to be broadcast in the respective antenna (50, 55) is effected as a function of the estimates of the radio channels (20, 25).

11. The radio station (1) of claim 9 [or 10], characterized in that a code generator (5) is provided, which expands the data transmitted with the signals with a code, wherein the code generator (5) ascertains the code as a function of a selected radio connection, and that the pre- equalization of the signal to be broadcast by the respective antenna (50, 55) is effected as a function of all the currently used codes and of the transmission properties of all the currently used radio channels.

12. A radio station (2) having at least two antennas (60, 65), characterized in that by means of the at least two antennas

(60, 65), the radio station (2) receives pre- equalized signals via a respective radio channel (20, 25).

13. The radio station (2) of claim 12, characterized in that a linear combination of the signals received via the at least two antennas (60, 65) is effected in the radio station (2), wherein the received signals are pre-equalized as a function of the superimposed transmission properties of the corresponding radio channels (20, 25), and that the linear combination is delivered to a demodulator (7).

Claims

1. A method for transmitting signals between a first radio station (1) and a second radio station (2), in which a pre-equalization of the signals to be transmitted is done in a modulator (4) of the first radio station (1), characterized in that the pre-equalized signals are transmitted from the first radio station (1) to the second radio station (2) via a plurality of radio channels (20, 25).

2. The method of claim 1, characterized in that one pre-equalized signal at a time is transmitted by a plurality of antennas (50, 55) of the first radio station (1) and via a respective radio channel (20, 25) to the second radio station (2), wherein for each radio channel (20, 25) an estimate of an impulse response is ascertained in the first radio station (1), and a pre-equalization of the signal to be broadcast from the applicable antenna (50, 55) is performed as a function of the estimate of the impulse responses of the radio channels (20, 25).

3. The method of claim 2, characterized in that a reference signal is transmitted from an antenna (60) of the second radio station (2) to the first radio station (1) via the radio channels (20, 25), and that the estimate of the impulse response of the respective radio channel (20, 25) is derived from a reception of the reference signal in the first radio station (1) via the respective radio channel (20, 25).

4. The method of claim 1, characterized in that a pre-equalized signal broadcast by the first radio station (1) is received by a plurality of antennas (60, 65) of the second radio

station (2), each via a respective radio channel (20, 25), and in the first radio station (1) an estimate of a total impulse response of all the radio channels (20, 25) is ascertained, and a pre-equalization of the signal to be broadcast by the first radio station (1) is performed as a function of the estimate of the total impulse response, and that the received signals formed by the antennas (60, 65) of the second radio station (2) are combined linearly and are then delivered to a demodulation.

5. The method of claim 4, characterized in that one reference signal is transmitted from the antennas (60, 65) of the second radio station (2) to the first radio station (1) via the associated radio channel (20, 25), and that the estimate of the total impulse response is derived from a superimposed reception of the reference signals in the first radio station (1).

6. The method of claim 5, characterized in that each reference signal is multiplied by a coefficient as a function of the radio channel (20, 25) used for its transmission, and that in the linear combination of the signals received by the antennas (60, 65) of the second radio station (2), each received signal is multiplied by the coefficient of the radio channel (20, 25) used for its transmission.

7. The method of claim 1, characterized in that via further radio channels, signals are transmitted between the first radio station (1) or the second radio station (2) and further radio stations (3), wherein the data from different radio stations transmitted with the signals is expanded with different codes, and that the pre- equalization is performed in the modulator (4) of the first radio station (1) as a function of all the different codes and of the transmission properties of all the

radio channels.

8. The method of claim 7, characterized in that the transmission properties of the radio channels are ascertained from data transmissions of the second radio station (2) and the further radio stations (3) to the first radio station (1).

9. A radio station (1) having a modulator (4), in which a pre-equalization of signals to be transmitted is effected in the modulator (4), characterized in that at least two antennas (50, 55) are provided, from which a broadcasting of the pre-equalized signals is effected, via a respective radio channel (20, 25), to a further radio station (2).

10. The radio station (1) of claim 9, characterized in that at least one channel estimator (11, 12) is provided, which for each radio channel (20, 25) ascertains an estimate of its impulse response, and that the pre-equalization of the signal to be broadcast in the respective antenna (50, 55) is effected as a function of the estimates of the radio channels (20, 25).

11. The radio station (1) of claim 9, characterized in that a code generator (5) is provided, which expands the data transmitted with the signals with a code, wherein the code generator (5) ascertains the code as a function of a selected radio connection, and that the pre- equalization of the signal to be broadcast by the respective antenna (50, 55) is effected as a function of all the currently used codes and of the transmission properties of all the currently used radio channels.

12. A radio station (2) having at least two antennas (60, 65), characterized in that by means of the at least two antennas

(60, 65), the radio station (2) receives pre- equalized signals via a respective radio channel (20, 25).

13. The radio station (2) of claim 12, characterized in that a linear combination of the signals received via the at least two antennas (60, 65) is effected in the radio station (2), wherein the received signals are pre-equalized as a function of the superimposed transmission properties of the corresponding radio channels (20, 25), and that the linear combination is delivered to a demodulator (7).

4|PRTS

09/830540
JC18 Rec'd PCT/PTO 26 APR 2001

# METHOD FOR TRANSMITTING SIGNALS BETWEEN A FIRST AND A SECOND RADIO STATION, AND RADIO STATION

## Prior Art

The invention is based on a method for transmitting signals between a first radio station and a second radio station, and on radio stations, as generically defined by the preambles to the independent claims.

From German Patent Application Serial No. 198 18 215, a method for transmitting signals between a base station and a plurality of mobile stations via radio channels is already known, in which the data from different mobile stations are expanded with different codes. A pre-equalization of the signals to be transmitted is performed in a modulator.

If pre-equalized data signals are transmitted to a receiver via a multi-way transmission channel, then transmission errors can occur as a result of strong fading incursions. Fading is understood to mean amplitude fluctuations that can occur in multi-way reception of a transmitted signal.

## Advantages of the Invention

The method and the radio stations according to the invention as defined by the characteristics of the independent claims have the advantage over the prior art that the pre-equalized signals are transmitted from a transmitter of the first radio station to a receiver of the second radio station via a plurality of radio channels. In this way, it is assured that at the second radio station, the reception of

pre-equalized signals will take place without any substantial amplitude incursion.

By the provisions recited in the dependent claims, advantageous refinements of and improvements to the method and the radio stations of the independent claims are possible.

It is especially advantageous that one pre-equalized signal at a time is transmitted by a plurality of antennas of the transmitter of the first radio station and via a respective radio channel to the receiver of the second radio station, wherein for each radio channel an estimate of an impulse response is ascertained in the first radio station, and a pre-equalization of the signal to be broadcast from the applicable antenna is performed as a function of the estimate of the impulse responses of the radio channels. In this way it is assured that the transmission of signals between the first radio station and the second radio station via a plurality of radio channels is taken into account in the pre-equalization. Thus even in transmission via a plurality of radio channels, equalization of the received signals in the second radio station can be dispensed with, thus saving effort and expense in the second radio station.

An accurate estimate of the impulse response of the associated radio channel is obtained if a reference signal is transmitted from an antenna of the second radio station to the first radio station via the radio channels, and the estimate of the impulse response of the respective radio channel is derived from a reception of the reference signal in the first radio station via the respective radio channel.

An equalization for multi-channel reception of signals

from the first radio station in the second radio station is not even necessary, if, in a second embodiment, a pre-equalized signal broadcast by the transmitter of the first radio station is received by a plurality of antennas of the receiver of the second radio station each via a respective radio channel, and in the first radio station an estimate of a total impulse response of all the radio channels is ascertained, and a pre-equalization of the signal to be broadcast by the first radio station is performed as a function of the estimate of the total impulse response. Also in this way, for the pre-equalization of the signal to be broadcast from the first radio station, the multi-channel transmission between the first radio station and the second radio station is taken into account.

An accurate estimate of the total impulse response is possible by transmission of a respective reference signal from the antennas of the second radio station to the first radio station via the associated radio channel, and the estimate of the total impulse response is derived from a superimposed reception of the reference signals in the first radio station. Pre-equalized signals transmitted from the first radio station to the second radio station then need merely be linearly combined in the second radio station and can subsequently be delivered to a demodulation without equalization. This saves effort and expense in the radio station as well.

It is especially advantageous that each reference signal is multiplied by a coefficient as a function of the radio channel used for its transmission, and that in the linear combination of the received signals formed by the antennas of the receiver, each received signal is multiplied by the coefficient of the radio channel used for its

transmission. By a suitable choice of the coefficient, an alignment characteristic of the antennas of the second radio station in the direction of the first radio station can be achieved, so that a transmission of signals between the first radio station and the second radio station also requires less transmission power.

A further advantage is that via further radio channels, signals are transmitted between the first radio station or the second radio station and further radio stations, wherein the data from different radio stations transmitted with the signals is expanded with different codes, and that the pre-equalization is performed in the modulator of the first radio station as a function of all the different codes and of the transmission properties of all the radio channels. In this way, the pre-equalization can be further improved, so that even so-called inter-symbol interference (ISI) between transmitted data symbols of one radio station and multiple access interference (MAI), that is, interference from other radio stations, can be taken into account in the pre-equalization, so that even that kind of interference requires no equalization in the second radio station.

Drawing

Exemplary embodiments of the invention are shown in the drawing and described in further detail in the ensuing description. Fig. 1 shows the general layout of a mobile radio system or mobile telephone system; Fig. 2 is a block circuit diagram of a first embodiment for a first and second radio station; Fig. 3 shows a second embodiment for the first and second radio stations; and Fig. 4 shows a chronological flow chart of the method of the invention.

Description of the Exemplary Embodiments

Fig. 1 schematically shows a radio cell of a cellular mobile telephone system or mobile radio system, with a first radio station 1 embodied as a base station, a second radio station 2 embodied as a mobile station, and further radio stations 3, also embodied as mobile stations. What is essential in this system is that an exchange of data always takes place only between the base station 1 and the mobile stations 2, 3, and no direct data exchange between the mobile stations 2, 3 is possible. Accordingly, the base station 1 is also called a central station, while the base stations 2, 3 are called peripheral stations. The exchange of data between the base station 1 and the mobile stations 2, 3 takes place by radio transmission. The radio transmission from the base station 1 to one of the mobile stations 2, 3 is called a downlink, while the data transmission from one of the mobile stations 2, 3 to the base station 1 is called an uplink. In such a system, shown in Fig. 1, with a central or base station 1 and a plurality of peripheral or mobile stations 2, 3, it must be defined how the data for the various mobile stations 2, 3 will be modulated, so that they can be detected separately in the receivers of the various mobile stations 2, 3. The system of Fig. 1 involves what is known as a CDMA system (code division multiple access system), in which for the data transmission a common frequency band is available, and the individual radio channels between the base station 1 and the various mobile stations 2, 3 differ from one another in terms of a code with which the signal for the applicable mobile station 2, 3 is expanded. This kind of coding is not necessary, however, if besides the base station 1 there is only a single mobile station 2, 3 in the radio cell. Below, the case in which there are a plurality of mobile stations 2, 3 in the radio cell along with the base station 1 will be

described. As a result of the expansion with the code, each signal that is to be exchanged between the base station 1 and a certain mobile station 2, 3 is distributed over the entire available spectrum. Each individual information bit to be transmitted is broken down into many small "chips". As a result, the energy of one bit is distributed over the entire frequency spectrum that is available to the CDMA system. In Fig. 2, a CDMA system is explained in greater detail in terms of a downlink transmission. Fig. 2 again shows the first radio station 1, embodied as a base station, and the second radio station 2, embodied as a mobile station. The base station 1 includes a first antenna 50. The second radio station 2 includes a third antenna 60 and a fourth antenna 65. The first radio station 1 and the second radio station 2 thus exchange data via a first radio channel 20 and a second radio channel 25. The first radio channel 20 describes a transmission path between the first antenna 50 and the third antenna 60.

The second radio channel 25 describes a transmission path between the first antenna 50 and the fourth antenna 65. The first radio station 1 includes a first modulator 4, which prepares the data streams from data sources 70 for transmission via the first radio channel 20 and the second radio channel 25. To that end, the first modulator 4 also requires code information, which is made available by a code generator 5. As an example, in Fig. 2 two arrows from the data sources 70 to the first modulator 4 and two arrows from the code generator 5 to the first modulator 4 are shown, which represent two different data streams, or two different items of code information. In an actual system, a substantially greater number of data streams and items of code information will be processed simultaneously. From the data streams and the code information, the first modulator 4

generates a transmission signal, which is transmitted to the second radio station 2 and the further radio stations 3. In Fig. 2, by way of example only the second radio station 2 is shown in the form of a receiving mobile station. If only the second radio station 2 were provided as a receiving mobile station in the radio cell to be supplied with a single data stream, then only one code information would be needed in the first radio station 1. However, as a rule, the first radio station 1 simultaneously transmits over corresponding radio channels to the further radio stations 3 as well, whose respective data are likewise modulated with various codes. For the sake of simplicity, these further radio stations 3 are not shown in Fig. 2.

The code generator 5 generates codes as a function of selected radio connections to the mobile stations 2, 3. The data to be transmitted with the signals are expanded with these codes in the first modulator 4.

In the transmission between the first radio station 1 and the second radio station 2, many instances of interference occur. One kind of interference is called ISI (for inter-symbol interference) and occurs because a transmitted radio signal can reach the receiver over a plurality of different paths, and the arrival times at the receiver differ slightly. Hence this kind of interference in the affected radio channel is due to the fact that signals transmitted earlier interfere with signals being received at the moment (hence the term inter-symbol interference). Another kind of interference is due to the fact that a plurality of data streams are transmitted simultaneously but differ only in terms of the code. This interference occurs when the base station 1 is in simultaneous radio contact with a plurality of mobile stations 2, 3, which is the rule in

modern mobile phone systems. Hence this kind of interference originates in the signals of different users and is therefore also known as MAI (for multiple access interference).

Fig. 2 also shows the receiving part of the second radio station 2, embodied as a mobile station, which is intended for receiving downlink data via the first radio channel 20 and the second radio channel 25. For this purpose a first demodulator 7 is provided, which processes the radio signals received via the third antenna 60 and the fourth antenna 65. The first demodulator 7 processes the received signals, so that from them it can generate a data stream for a data user 8. If the transmitted data are speech information, for instance, then the data user 8 is a speech decoder; with other kinds of data, it is for instance a computer or a fax machine. As a rule, mobile stations have only a single data user 8 and thus only a single data stream as well. If the transmission via the first radio channel 20 and the second radio channel 25 were completely without interference, then the first demodulator 7 for demodulation purposes would need merely to know the code information of the data to be detected for the user 8. However, because of the above-described kinds of interference, this is inadequate. A first channel estimator 11 is therefore provided in addition in the base station; it makes information about the transmission properties of all the radio channels between the base station 1 and the mobile stations 2, 3 available. The first modulator 4 then generates a transmission signal, which takes both the ISI and the MAI into account. The transmission signal in each case is designed such that each of the mobile stations 2, 3 upon reception receive an interference-free signal, as much as possible. Both the kinds of interference that are due to the simultaneous use of multiple codes and the kinds of

interference that arise from the transmission properties of the individual radio channels are taken into account. The receiver of the data, that is, the second radio station 2, is correspondingly of simple design as shown in Fig. 2. It has the first demodulator 7, which receives the signal of the third antenna 60 and the fourth antenna 65. The code information for the applicable data stream must also be made available to this first demodulator 7 by a further code generator 9, and from that the first demodulator 7 then generates the data stream for the data user 8. The second radio station 2 can thus be designed especially simply.

Fig. 2 has shown that in the downlink transmission, advantageously all the kinds of interference in the radio channels 20, 25 in the transmitting stations are taken into account in the downlink transmission, or in other words in the base station 1. The downlink part of the second radio station 2 and of the further radio stations 3 can therefore be especially simple in design. To keep these mobile stations 2, 3 simple for the uplink path as well, or in other words for sending data from the applicable mobile station 2, 3 to the base station 1, a method in accordance with the article by A. Klein, G. K. Kaleh and P. W. Beier, entitled "Zero forcing and minimum mean-square-error equalization for multi user detection in code-division-multiple-access channels", IEEE Trans. Vehic. Tech., vol. 45 (1996), pages 276-287, could be used; in this method, the ISI and the MAI are taken into account in the receiving station, or in other words again in the base station 1. To that end, the first channel estimator 11 would then be connected in addition to the second demodulator 75. In this way, a system becomes possible in which the mobile stations 2, 3 are especially simple in design, since the ISI and MAI are taken into account solely in the base station 1. In a corresponding TDD

system (time division duplex system), in which the downlink transmission and the uplink transmission take place in adjacent slots in the same frequency band, it is also very easily possible to obtain the channel transmission properties by means of the first channel estimator 11 in the base station 1, because the properties of the applicable transmission channels can be ascertained by evaluation of the received uplink data in the base station 1. The corresponding channel impulse response or channel quality can also be transmitted from the applicable mobile station 2, 3 to the base station 1 by means of a data telegram.

If only a single radio channel is used for the transmission from the first radio station 1 to the second radio station 2, then despite the pre-equalization of the signal to be transmitted in the first radio station 1, amplitude incursions of the corresponding received signal can occur in the second radio station 2. The amplitude fluctuations, also known as fading, of the signal received in the second radio station 2 result from multi-path reception or radio obstruction when the second radio station 2 embodied as a mobile station is in motion, for instance in the vicinity of buildings. To prevent the amplitude fluctuations caused by multi-way reception, the transmission between the first radio station 1 and the second radio station 2 takes place via the two radio channels 20, 25. This will be described in further detail below in conjunction with Fig. 2. The first radio channel 20 forms a transmission path between the first antenna 50 and the third antenna 60, and the radio channel 25 forms a transmission path between the first antenna 50 and the fourth antenna 65. If on one of the two transmission paths an amplitude incursion of the signal transmitted over this transmission path occurs, then the signal can still be received with adequate amplitude in the

second radio station 2 by way of the other one of the two transmission paths.

The first radio station 1 also includes a first transceiver 30, which includes an antenna switch and optionally a transmission/reception amplifier, and a second demodulator 75. The first antenna 50 is a transmitting/receiving antenna, so that the antenna switch in the first transceiver 30 serves to switch back and forth between the transmission and reception directions. In the transmission direction, the antenna switch of the first transceiver 30 connects the first modulator 4 to the first antenna 50. In the reception direction, the antenna switch of the first transceiver 30 connects the first antenna 50 to the second demodulator 75, which demodulates the received signals and sends them on to one or more data sinks. The received signals delivered to the second demodulator 75 are also delivered to the first channel estimator 11, which ascertains an estimate of a total impulse response of the two radio channels 20, 25 between the first radio station 1 and the second radio station 2 and sends this estimate on to the first modulator 4. The pre-equalization of the signal to be broadcast by the first antenna 50 of the first radio station 1 is then done in the first modulator 4 as a function of the estimate of the total impulse response. In the second radio station 2, the third antenna 60 is connected to a third transceiver 40, and the fourth antenna 65 is connected to a fourth transceiver 45. The third antenna 60 and the fourth antenna 65 are again each embodied as a transmitting/receiving antenna, so that in the third transceiver 40 and the fourth transceiver 45 there is each one antenna switch, to enable switching over between the two transmission directions. The second radio station 2 includes a second modulator 6, which in the case of transmission is

connected via the applicable antenna switch of the third transceiver 40 and the fourth transceiver 45 to both the third antenna 60 and the fourth antenna 65. In the case of reception, the applicable antenna switch of the third transceiver 40 and the fourth transceiver 45 connects the third antenna 60 and the fourth antenna 65 to the first demodulator 7, via an addition member 80. Before the addition of the two received signals by the addition member 80, the received signal furnished by the third transceiver 40 is multiplied by a first coefficient $c_1$, and the received signal furnished by the fourth transceiver 45 is multiplied by a second coefficient $c_2$. Conversely, in the case of transmission, transmitted data delivered to the second modulator 6 are multiplied, after their modulation in the second modulator 6, on the one hand by the first coefficient $c_1$ and delivered to the third antenna 60 via the third transceiver 40, and on the other are multiplied by the second coefficient $c_2$ and delivered to the fourth antenna 65, via the fourth transceiver 45.

By a suitable choice of the coefficients $c_1$, $c_2$, a directional effect or directional characteristic of the signals to be broadcast or received by the third antenna 60 and the fourth antenna 65 can be achieved, which is advantageously aimed at the first radio station 1. In this way, signal incursions from fading can also be counteracted. Via the addition member 80, the received signals furnished by the third antenna 60 and the fourth antenna 65 are combined linearly and then delivered for demodulation in the first demodulator 7. The first coefficient $c_1$ is associated with the first radio channel 20, and the second coefficient $c_2$ is associated with the second radio channel 25. In the second modulator 6, reference signals can be formed, which after multiplication by the first coefficient $c_1$ or the second

coefficient $c_2$ are transmitted to the first radio station 1 via the associated radio channel 20, 25. The estimate of the total impulse response in the first channel estimator 11 is derived from the superimposed reception of the reference signals in the base station 1.

In Fig. 3, the same reference numerals identify elements that are the same as in Fig. 2. Unlike Fig. 2, the first radio station 1 now has not only the first antenna 50 but also a second antenna 55 while conversely the second radio station 2 includes only the third antenna 60. The first radio channel 20 in Fig. 3 now defines the transmission path between the first antenna 50 and the third antenna 60, and the second radio channel 25 defines the transmission path between the second antenna 55 and the third antenna 60. Thus in Fig. 3, in the second radio station 2 only the third transceiver 40 is necessary, which in turn includes one antenna switch for both of the possible transmission directions; this antenna switch on the one hand connects the second modulator 6 to the third antenna 60 and on the other connects the first demodulator 7 to the third antenna 60, as a function of the transmission direction. The first radio station 1, conversely, now includes in addition to the first transceiver 30 a second transceiver 35, which likewise includes an antenna switch that connects the second antenna 55 to the first modulator 4 for transmission, and for reception connects it to the second demodulator 75 and also, via a second channel estimator 12, to the first modulator 4. The second channel estimator 12 can additionally, as shown in Fig. 3, be connected to the second demodulator 75 as well, in order to eliminate ISI and MAI from the received signals.

In this way, one pre-equalized signal each is broadcast by the first antenna 50 and the second antenna 55 and

transmitted via the first radio channel 20 and the second radio channel 25, respectively, to the third transceiver 40; for the first radio channel 20, an estimate of its impulse response is ascertained in the first channel estimator 11, and for the second radio channel 25, an estimate of its impulse response is ascertained in the second channel estimator 12. The pre-equalization of the signal to be broadcast by the first antenna 50 is then performed in the first modulator 4 as a function of the estimate of the impulse response of the first radio channel 20 and the estimate of the impulse response of the second radio channel 25, and the pre-equalization of the signal to be broadcast by the second antenna 55 is performed in the first modulator 4 as a function of the estimate of the impulse response of the first radio channel 20 and the estimate of the impulse response of the second radio channel 25. By the third antenna 60 of the second radio station 2, a reference signal is transmitted to the first radio station 1, via the two radio channels 20, 25 and the first antenna 50 and the second antenna 55. The estimate of the impulse response of the first radio channel 20 is then derived in the first channel estimator 11 from the reception of the reference signal via the first radio channel 20, and the estimate of the impulse response of the second radio channel 25 is derived in the second channel estimator 12 from the reception of the reference signal via the second radio channel 25.

The pre-equalization of the signal to be broadcast by the first antenna 50 and by the second antenna 55 is done as a function of all the codes currently used in the radio cell of the first radio station 1 and as a function of the transmission properties of all the radio channels currently used there, which are ascertained in the two channel estimators 11, 12. This is also true for the exemplary

embodiment of Fig. 2, using only the first antenna 50 to broadcast signals from the first radio station 1, and using only the first channel estimator 11.

It can also be provided that both the first radio station 1 and the radio station 2 are each equipped with two antennas, resulting in four radio channels that make even better protection against fading possible. In the first radio station 1 and the second radio station 2, it is also possible arbitrarily to use more antennas, so that an arbitrary number of radio channels can be set up between the first radio station 1 and the second radio station 2; as the number of radio channels between the first radio station 1 and the second radio station 2 increases, the influence of fading on the signal transmission decreases.

It can also be provided that the pre-equalization be done not in the base station 1 but in the mobile stations 2, 3 in a corresponding way. The multi-channel transmission method between the base station 1 and the mobile stations 2, 3, which will hereinafter be called users, and in which the transmission properties of all the radio channels (ISI) and the codes of all the radio channels (MAI) are taken into account, will be described below by mathematical formulas. These formulas can be realized either by means of a suitable program or suitable hardware modules that implement these formulas.

Fig. 4 shows a chronological flow chart in TDD operation with pre-equalization. In a first step 100, the second radio station 2 sends reference signals for estimating the transmission properties of the two radio channels 20, 25 to the first radio station 1. This channel estimation is performed in a second step 105 in the first radio station 1

after the reference signals have been received. Next, in the first modulator 4 of the first radio station 1, a pre-equalization of the signals to be transmitted to the radio station 2 takes place in a third step 110. The pre-equalized signals are then received by the second radio station 2 in a fourth step 115 and require no further equalization there.

As a first example, two-channel transmission between the first antenna 50 and the third antenna 60, or the fourth antenna 65, will be described in accordance with Fig. 2. The second radio station 2 is meant to represent one of a plurality of users.

A discrete-time multiple transmission system with blockwise transmission is assumed. Let $\underline{d}^{(k)} = (d^{(k)}{}_1, \ldots, d^{(k)}{}_M)$, where $k = 1, \ldots, K$, be the vector of the M data symbols, to be transmitted, of a data block of the $k^{th}$ user. $\underline{d} = (\underline{d}^{(1)}, \ldots, \underline{d}^{(K)})$ designates the summarization of all the data symbols to be transmitted. Let each of the K users be assigned a CDMA code $\underline{c}^{(k)} = (c^{(k)}{}_1, \ldots, c^{(k)}{}_Q)$, where $k = 1, \ldots, K$, of length Q. By expanding the data bits, which are to be transmitted, with the CDMA codes, each bit is distributed to Q so-called chips. A chip clock period amounts to precisely 1/Q of the bit clock period. With the code matrix

$$C^{(k)} = \underbrace{\begin{pmatrix} \underline{c}^{(k)T} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & \underline{c}^{(k)T} \end{pmatrix}}_{M} \left.\vphantom{\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}}\right\} M \cdot Q, \quad k = 1, \ldots, K$$

$\underline{c}^{(k)T}$ = transposed vector $\underline{c}^{(k)}$

of the $k^{th}$ user, the expansion of a data block of the $k^{th}$ user

can be written as:

$$C^{(k)} \cdot \underline{d}^{(k)T}.$$

The entire block of M data bits is distributed among M•Q chips. Combining the chip clock signals of all the users yields

$$C \cdot \underline{d}^T$$

and the matrix

$$C = \begin{pmatrix} C^{(1)} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & C^{(K)} \end{pmatrix}$$

summarizes the code matrixes of all the users.

After the modulation, the signals are linearly pre-equalized according to the invention. In Figs. 2 and 3, the steps of modulation and pre-equalization, which are handled mathematically separately here, are performed by the first modulator 4. Let the pre-equalization be written by means of the matrix P. The result is the transmission signal $\underline{s}$:

$$\underline{s}^T = P \cdot C \cdot \underline{d}^T.$$

$\underline{s}$ reaches the $k^{th}$ user via the two radio channels 20, 25 in the exemplary embodiment of Fig. 2. Let $\underline{h}^{(k,l)} = (h_1^{(k,l)}, \ldots, h_W^{(k,l)})$, where $k = 1, \ldots, K$, and $l = 1, 2$, represent the impulse responses of the two radio channels 20, 25 for the $k^{th}$ user with respect to the chip clock frequency. W is the number of chip clock periods over which a multi-way reception

is taken into account. By means of the multi-way channel, the data blocks of the chip clock length M•Q are stretched out to M•Q+W-1 chip pulses. The last W-1 chip card are superimposed on the first W-1 chip card of the next data block. The demodulator of the k$^{th}$ user receives not only the multi-way signal per radio channel 20, 25 but generally also additive noise

$\underline{n}^{(k,l)} = (n^{(k,l)}_{1}, \ldots, n^{(k,l)}_{M\cdot Q+W-1})$, where k = 1, ..., K, and l = 1, 2, of length M•Q+W-1.

With the matrixes

$$H^{(k,l)} = \left.\underbrace{\begin{pmatrix} h^{(k,l)}_1 & 0 & 0 \\ \vdots & \ddots & 0 \\ h^{(k,l)}_W & \vdots & h^{(k,l)}_1 \\ 0 & \ddots & \vdots \\ 0 & 0 & h^{(k,l)}_W \end{pmatrix}}_{M\cdot Q}\right\} M\cdot Q+W-1$$

$$D = \left.\underbrace{\begin{pmatrix} 1 & 0 & 0 & 1 & 0 & 0 & \cdots \\ 0 & \ddots & 0 & 0 & \ddots & 0 & \cdots \\ 0 & 0 & 1 & 0 & 0 & 1 & \cdots \end{pmatrix}}_{M\cdot Q\cdot K}\right\} M\cdot Q$$

the demodulator of the k$^{th}$ user of the system accordingly receives the two reception signals

$\underline{r}^{(k,l)T} = H^{(k,l)}\cdot D\cdot P\cdot C\cdot \underline{d}^{T}+\underline{n}^{(k,l)T}$,
where l = 1, 2 and k = 1, ..., K.

The matrix D adds up the pre-equalized chip clock signals of all the users, so that they can be broadcast via

an antenna.

The two received signals $\underline{r}^{(k,l)}$, where $l = 1, 2$ and $k = 1, \ldots, K$, are first linearly combined by the addition member 80 to form

$$\underline{r}^{(k)} = c_1\underline{r}^{(k,1)} + c_2\underline{r}^{(k,2)}.$$

A suitable demodulator of the $k^{th}$ user in accordance with Fig. 2 can be embodied as a simple "matched filter", which compresses the received chip clock signal with the CDMA code of the desired data signal. This "matched filter" receiver (1-finger rake receiver) for the $k^{th}$ user code $\underline{c}^{(k)}$:

$$R^{(k)} = \left.\underbrace{\begin{pmatrix} 0 & 0 & 0 \\ \vdots & \vdots & \vdots \\ 0 & & \\ \underline{c}^{(k)T} & 0 & \\ 0 & \ddots & 0 \\ 0 & 0 & \underline{c}^{(k)T} \end{pmatrix}}_{M}\right\} M \cdot Q + W - 1$$

demodulates the linearly combined received signals into

[paste in German page 20, the line between lines 5 and 10]

where $R^{(k)H}$ = conjugated complex transposed matrix $R(k)$.

With the summarizations

[paste in German page 20, bottom three equations]

$$R=\begin{pmatrix} R^{(1)} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & R^{(K)} \end{pmatrix}$$

$$H=\begin{pmatrix} c_1H^{(1,1)}+c_2H^{(1,2)} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & c_1H^{(K,1)}+c_2H^{(K,2)} \end{pmatrix}$$

$$\underline{n}=(c_1\cdot\underline{n}^{(1,1)}+c_2\cdot\underline{n}^{(1,2)},\ldots,c_1\cdot\underline{n}^{(K,1)}+c_2\cdot\underline{n}^{(K,2)})$$

all the demodulated signals are received as a total vector:

$$\hat{\underline{d}}=R^H\cdot H\cdot D^T\cdot D\cdot P\cdot C\cdot\underline{d}^T+R^H\cdot\underline{n}^T$$

The $M\cdot K\text{x}M\cdot Q\cdot K$ matrix $R^H\cdot H\cdot D^T\cdot D$ in general has the rank of $M\cdot K$. Therefore $(R^H\cdot H\cdot D^T\cdot D)\cdot(R^H\cdot H\cdot D^T\cdot D)$ is invertable, and the following is true:

$$P=(R^H\cdot H\cdot D^T\cdot D)^H\cdot\left[(R^H\cdot H\cdot D^T\cdot D)\cdot(R^H\cdot H\cdot D^T\cdot D)^H\right]^{-1}\cdot\underline{d}^T\cdot\frac{1}{\left\|C\cdot\underline{d}^T\right\|^2}\cdot(C\cdot\underline{d}^T)^H$$

With this choice, the following becomes true

$$\hat{\underline{d}}^T=\underline{d}^T+R^H\cdot\underline{n}^T$$

$R^H$ thus furnishes the transmitted data symbols $\underline{d}^T$ and additive noise. Despite the use of a very simple receiver, the detected signal contains neither ISI nor MAI. These kinds of interference are eliminated on the transmitter side by means of pre-equalization.

H can simply be estimated by the first channel estimator 11 of the first radio station 1.

A reference signal $\underline{p}^{(k)}$ of the $k^{th}$ user, transmitted in the uplink transmission for channel estimation, is sent via the third antenna 60 in the form $c_1 \bullet \underline{p}^{(k)}$ and via the fourth antenna 65 in the form $c_2 \bullet \underline{p}^{(k)}$. The base station 1 therefore receives the corresponding signal

$$H^{(k,1)} \bullet c_1 \bullet \underline{p}^{(k)} + H^{(k,2)} \bullet c_2 \bullet \underline{p}^{(k)} = c_1 \bullet H^{(k,1)} \bullet \underline{p}^{(k)} + c_2 \bullet H^{(k,2)} \bullet \underline{p}^{(k)},$$

and estimates the total impulse response of the two radio channels 20, 25 of the $k^{th}$ user as $\underline{h}^{(k)} = c_1 \bullet h^{(k,1)} + c_2 \bullet h^{(k,2)}$.

Second, the method for signal transmission between the base station 1 and the mobile stations 2, 3 will be described in accordance with Fig. 3, in which the multi-channel transmission takes place between the base station 1 and each of the mobile stations 2, 3 via two radio channels 20, 25 each; transmission is done both between the first antenna 50 and the third antenna 60 and between the second antenna 55 and the third antenna 60 in Fig. 3.

Once again a discrete-time multiple transmission system with blockwise transmission is assumed. Let $\underline{d}^{(k)} = (d^{(k)}_1, \ldots, d^{(k)}_M)$, where $k = 1, \ldots, K$, be the vector of the M data symbols, to be transmitted, of a data block of the $k^{th}$ user. $\underline{d} = (\underline{d}^{(1)}, \ldots, \underline{d}^{(K)})$ designates the summarization of all the data symbols to be transmitted. Let each of the K users be assigned a CDMA code $\underline{c}^{(k)} = (c^{(k)}_1, \ldots, c^{(k)}_Q)$, where $k = 1, \ldots, K$, of length Q. By expanding the data bits, which are to be transmitted, with the CDMA codes, each bit is distributed to Q so-called chips. A chip clock period amounts to precisely 1/Q of the bit clock period. With the

code matrix

$$C^{(k)} = \underbrace{\begin{pmatrix} \underline{c}^{(k)T} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & \underline{c}^{(k)T} \end{pmatrix}}_{M} \Bigg\} M \cdot Q,\ k = 1,\ldots,K$$

$\underline{c}^{(k)T}$ = transposed vector $\underline{c}^{(k)}$

of the $k^{th}$ user, the expansion of a data block of the $k^{th}$ user can be written as:

$$C^{(k)} \bullet \underline{d}^{(k)T}.$$

The entire block of M data bits is distributed among M•Q chips. Combining the chip clock signals of all the users yields

$$C \bullet \underline{d}^T$$

and the matrix

$$C = \begin{pmatrix} C^{(1)} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & C^{(K)} \end{pmatrix}$$

summarizes the code matrixes of all the users.

After the modulation, the signals are linearly pre-equalized according to the invention. In Figs. 2 and 3, the steps of modulation and pre-equalization, which are handled mathematically separately here, are performed by the first modulator 4. Let the pre-equalization be written by means of

the matrix P.

The resultant transmission signals $\underline{s}^{(l)}$, where l = 1, 2, of the first antenna 50 and the second antenna 55 are assumed to be summarized in a total signal vector $\underline{s} = (\underline{s}^{(1)}, \underline{s}^{(2)})$, where:

$$\underline{s}^T = P \cdot C \cdot \underline{d}^T.$$

The total signal vector $\underline{s}$ reaches the $k^{th}$ user via the two radio channels 20, 25 in the exemplary embodiment of Fig. 3. Let $\underline{h}^{(k,l)} = (h_1^{(k,l)}, \ldots, h_W^{(k,l)})$, where k = 1, ..., K, and l = 1, 2, represent the impulse responses of the two radio channels 20, 25 for the $k^{th}$ user with respect to the chip clock frequency. W is the number of chip clock periods over which a multi-way reception is taken into account. By means of the multi-way channel, the data blocks of the chip clock length M•Q are stretched out to M•Q+W-1 chip pulses. The last W-1 chip card are superimposed on the first W-1 chip card of the next data block. The demodulator of the $k^{th}$ user receives not only the multi-way signal per radio channel 20, 25 but generally also the additive noise $\underline{n}^{(k,l)} = (n^{(k,l)}_1, \ldots, n^{(k,l)}_{M \cdot Q+W-1})$, where k = 1, ..., K, and l = 1, 2, of length M•Q+W-1.

With the matrixes

$$H^{(k,l)} = \underbrace{\begin{pmatrix} h^{(k,l)}_1 & 0 & 0 \\ \vdots & \ddots & 0 \\ h^{(k,l)}_W & \vdots & h^{(k,l)}_1 \\ 0 & \ddots & \vdots \\ 0 & 0 & h^{(k,l)}_W \end{pmatrix}}_{M \cdot Q} \left.\vphantom{\begin{pmatrix} 0\\0\\0\\0\\0 \end{pmatrix}}\right\} M \cdot Q + W - 1$$

$$D = \underbrace{\begin{pmatrix} D_0 & 0 \\ 0 & D_0 \end{pmatrix}}_{2 \cdot M \cdot Q \cdot K} \Big\} 2 \cdot M \cdot Q$$

$$D_0 = \underbrace{\begin{pmatrix} 1 & 0 & 0 & 1 & 0 & 0 & \cdots \\ 0 & \ddots & 0 & 0 & \ddots & 0 & \cdots \\ 0 & 0 & 1 & 0 & 0 & 1 & \cdots \end{pmatrix}}_{M \cdot Q \cdot K} \Big\} M \cdot Q$$

the demodulator of the $k^{th}$ user of the system receives the signal

$$\underline{r}^{(k)T} = H^{(k,1)},\ H^{(k,2)} \cdot D \cdot P \cdot C \cdot \underline{d}^T + \underline{n}^{(k,1)T} + \underline{n}^{(k,2)T}$$

A suitable demodulator of the $k^{th}$ user in accordance with Fig. 3 can be embodied as a simple "matched filter", which compresses the received chip clock signal with the CDMA code of the desired data signal. This "matched filter" receiver (1-finger rake receiver) for the $k^{th}$ user code $\underline{c}^{(k)}$:

$$R^{(k)} = \underbrace{\begin{pmatrix} 0 & 0 & 0 \\ \vdots & \vdots & \vdots \\ 0 & & \\ \underline{c}^{(k)T} & 0 & \\ 0 & \ddots & 0 \\ 0 & 0 & \underline{c}^{(k)T} \end{pmatrix}}_{M} \Bigg\} M \cdot Q + W - 1$$

demodulates the received signal into

$$\hat{\underline{d}}^{(k)T} = R^{(k)H} \cdot \underline{r}^{(k)T}$$

where $R^{(k)H}$ = conjugated complex transposed matrix $R^{(k)}$.

With the summarizations

$$R=\begin{pmatrix} R^{(1)} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & R^{(K)} \end{pmatrix}$$

$$H=\begin{pmatrix} H^{(1,1)} & 0 & 0 & H^{(1,2)} & 0 & 0 \\ 0 & \ddots & 0 & 0 & \ddots & 0 \\ 0 & 0 & H^{(K,1)} & 0 & 0 & H^{(K,2)} \end{pmatrix}$$

$$\underline{n}=(\underline{n}^{(1,1)}+\underline{n}^{(1,2)},\ldots,\underline{n}^{(K,1)}+\underline{n}^{(K,2)})$$

all the demodulated signals are received as a total vector:

$$\hat{\underline{d}}=R^{H}\cdot H\cdot D^{T}\cdot D\cdot P\cdot C\cdot\underline{d}^{T}+R^{H}\cdot\underline{n}^{T}$$

The M•KxM•Q•K matrix $R^{H}\cdot H\cdot D^{T}\cdot D$ in general has the rank of M•K. Therefore $(R^{H}\cdot H\cdot D^{T}\cdot D)\cdot(R^{H}\cdot H\cdot D^{T}\cdot D)$ is invertable, and the following is true:

$$P=(R^{H}\cdot H\cdot D^{T}\cdot D)^{H}\cdot\left[(R^{H}\cdot H\cdot D^{T}\cdot D)\cdot(R^{H}\cdot H\cdot D^{T}\cdot D)^{H}\right]^{-1}\cdot\underline{d}^{T}\cdot\frac{1}{\left\|C\cdot\underline{d}^{T}\right\|^{2}}\cdot(C\cdot\underline{d}^{T})^{H}$$

With this choice, the following becomes true

$$\hat{\underline{d}}^{T}=\underline{d}^{T}+R^{H}\cdot\underline{n}^{T}$$

$R^{H}$ thus furnishes the transmitted data symbols $\underline{d}^{T}$ and additive noise. Despite the use of a very simple receiver, the detected signal contains neither ISI nor MAI. These kinds of interference are eliminated on the transmitter side by means of pre-equalization.

H can simply be estimated by the two channel estimators 11, 12 of the first radio station 1.

Claims

1. A method for transmitting signals between a first radio station (1) and a second radio station (2), in which a pre-equalization of the signals to be transmitted is done in a modulator (4) of the first radio station (1), characterized in that the pre-equalized signals are transmitted from the first radio station (1) to the second radio station (2) via a plurality of radio channels (20, 25).

2. The method of claim 1, characterized in that one pre-equalized signal at a time is transmitted by a plurality of antennas (50, 55) of the first radio station (1) and via a respective radio channel (20, 25) to the second radio station (2), wherein for each radio channel (20, 25) an estimate of an impulse response is ascertained in the first radio station (1), and a pre-equalization of the signal to be broadcast from the applicable antenna (50, 55) is performed as a function of the estimate of the impulse responses of the radio channels (20, 25).

3. The method of claim 2, characterized in that a reference signal is transmitted from an antenna (60) of the second radio station (2) to the first radio station (1) via the radio channels (20, 25), and that the estimate of the impulse response of the respective radio channel (20, 25) is derived from a reception of the reference signal in the first radio station (1) via the respective radio channel (20, 25).

4. The method of claim 1, 2 or 3, characterized in that a pre-equalized signal broadcast by the first radio station (1) is received by a plurality of antennas (60, 65) of the second radio station (2), each via a respective radio

channel (20, 25), and in the first radio station (1) an estimate of a total impulse response of all the radio channels (20, 25) is ascertained, and a pre-equalization of the signal to be broadcast by the first radio station (1) is performed as a function of the estimate of the total impulse response, and that the received signals formed by the antennas (60, 65) of the second radio station (2) are combined linearly and are then delivered to a demodulation.

5. The method of claim 4, characterized in that one reference signal is transmitted from the antennas (60, 65) of the second radio station (2) to the first radio station (1) via the associated radio channel (20, 25), and that the estimate of the total impulse response is derived from a superimposed reception of the reference signals in the first radio station (1).

6. The method of claim 5, characterized in that each reference signal is multiplied by a coefficient as a function of the radio channel (20, 25) used for its transmission, and that in the linear combination of the signals received by the antennas (60, 65) of the second radio station (2), each received signal is multiplied by the coefficient of the radio channel (20, 25) used for its transmission.

7. The method of one of the foregoing claims, characterized in that via further radio channels, signals are transmitted between the first radio station (1) or the second radio station (2) and further radio stations (3), wherein the data from different radio stations transmitted with the signals is expanded with different codes, and that the pre-equalization is performed in the modulator (4) of the first radio station (1) as a function of all the different codes and of the transmission properties of all the radio channels.

8. The method of claim 7, characterized in that the transmission properties of the radio channels are ascertained from data transmissions of the second radio station (2) and the further radio stations (3) to the first radio station (1).

9. A radio station (1) having a modulator (4), in which a pre-equalization of signals to be transmitted is effected in the modulator (4), characterized in that at least two antennas (50, 55) are provided, from which a broadcasting of the pre-equalized signals is effected, via a respective radio channel (20, 25), to a further radio station (2).

10. The radio station (1) of claim 9, characterized in that at least one channel estimator (11, 12) is provided, which for each radio channel (20, 25) ascertains an estimate of its impulse response, and that the pre-equalization of the signal to be broadcast in the respective antenna (50, 55) is effected as a function of the estimates of the radio channels (20, 25).

11. The radio station (1) of claim 9 or 10, characterized in that a code generator (5) is provided, which expands the data transmitted with the signals with a code, wherein the code generator (5) ascertains the code as a function of a selected radio connection, and that the pre-equalization of the signal to be broadcast by the respective antenna (50, 55) is effected as a function of all the currently used codes and of the transmission properties of all the currently used radio channels.

12. A radio station (2) having at least two antennas (60, 65), characterized in that by means of the at least two

antennas (60, 65), the radio station (2) receives pre-equalized signals via a respective radio channel (20, 25).

13. The radio station (2) of claim 12, characterized in that a linear combination of the signals received via the at least two antennas (60, 65) is effected in the radio station (2), wherein the received signals are pre-equalized as a function of the superimposed transmission properties of the corresponding radio channels (20, 25), and that the linear combination is delivered to a demodulator (7).

METHOD FOR TRANSMITTING SIGNALS BETWEEN A FIRST AND A SECOND RADIO STATION, AND RADIO STATION


Abstract

A method and radio stations for transmitting signals between a first radio station (1) and a second radio station (2) are proposed, in which the influence of amplitude fluctuations or fading can be reduced. In a modulator (4) of the first radio station (1) a pre-equalization of the signals to be transmitted is performed. The pre-equalized signals are transmitted from the first radio station (1) to the second radio station (2) via a plurality of radio channels (20, 25).

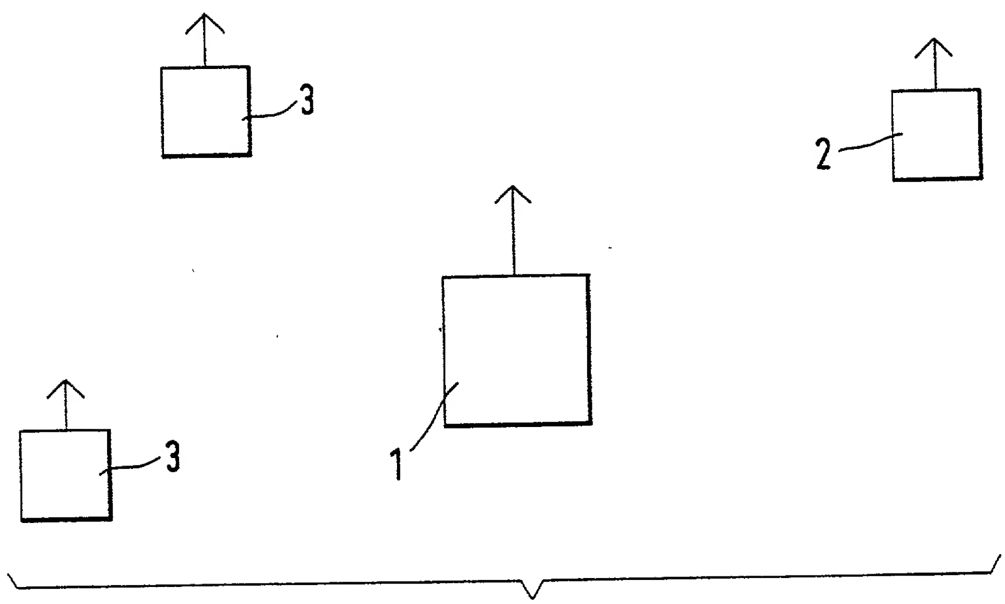



Fig.1

09/830540



Fig.2

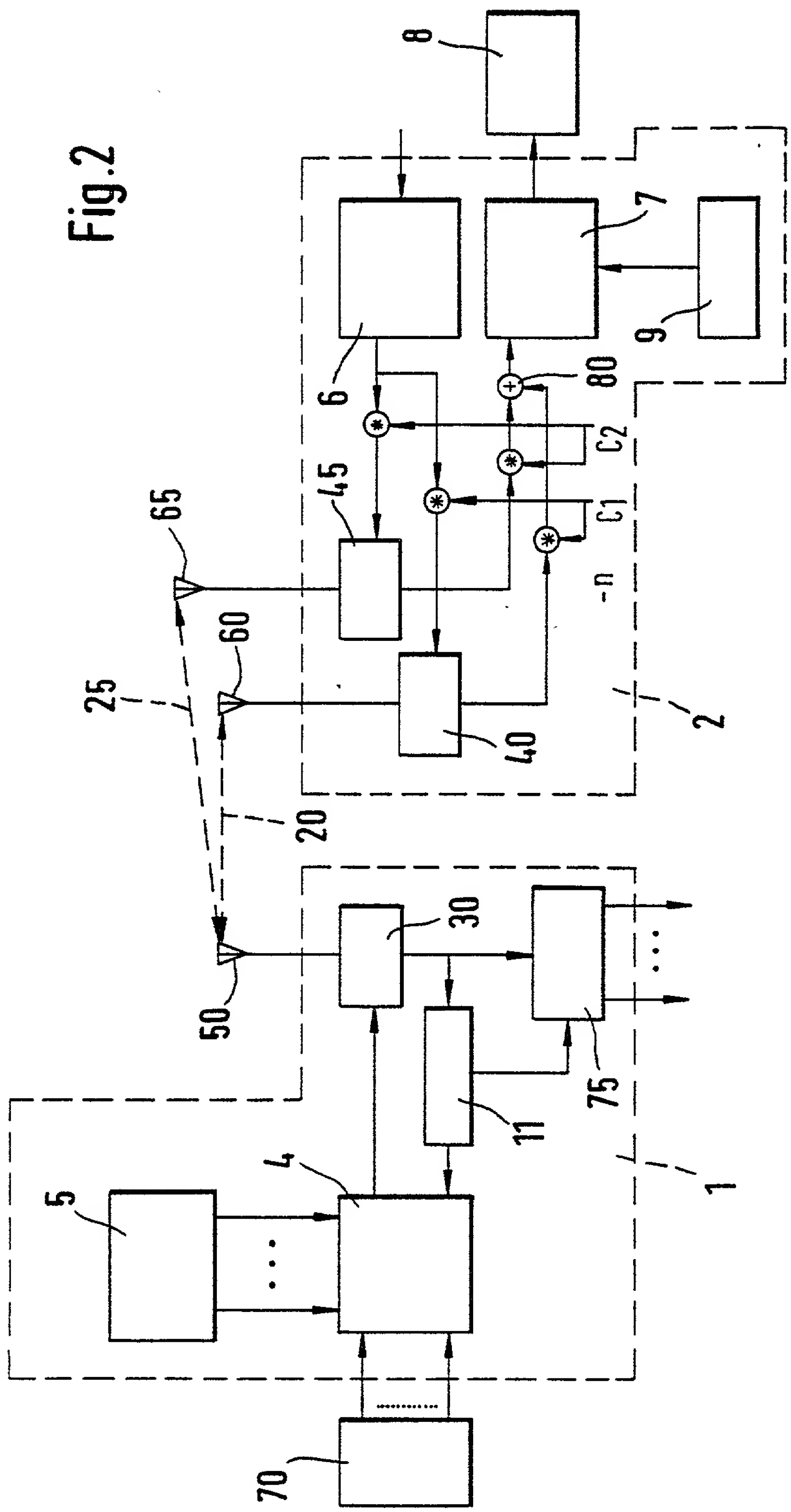
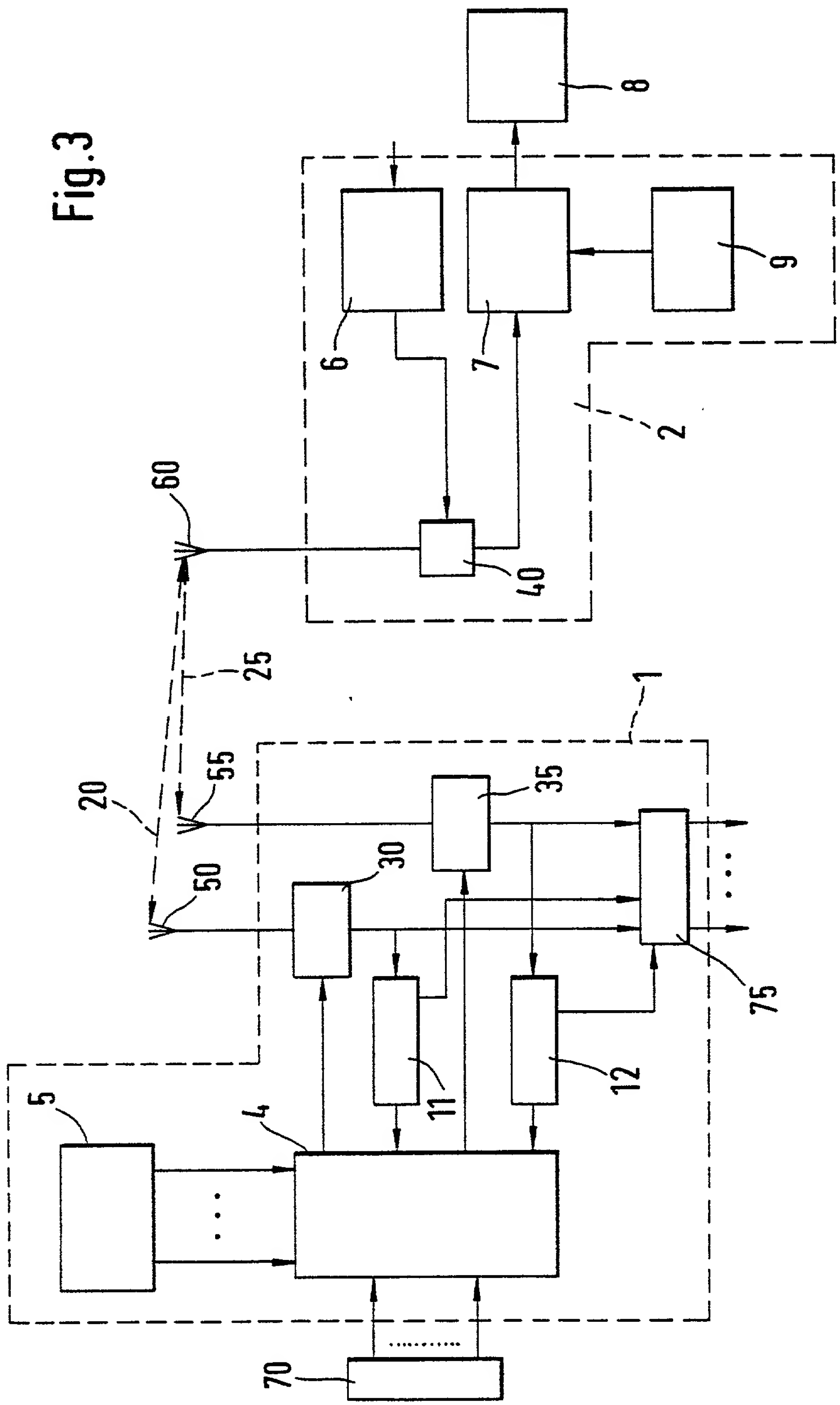


Fig.3



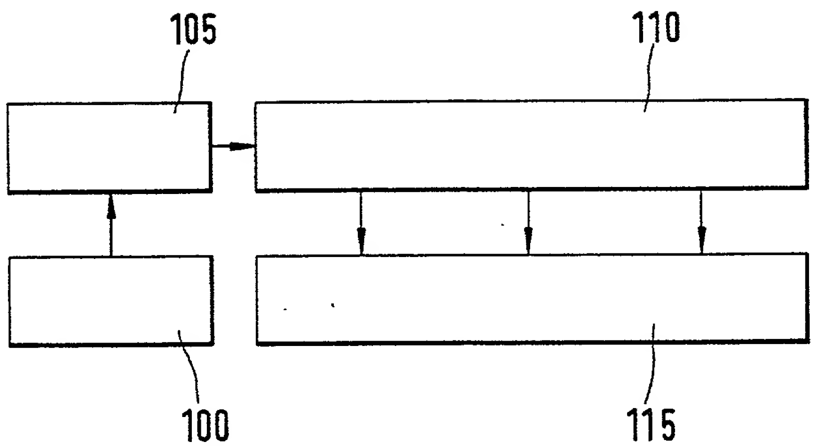



Fig.4

R. 34709

DECLARATION AND POWER OF ATTORNEY FOR NATIONAL STAGE OF PCT PATENT APPLICATION

As a below-named inventor, I hereby declare that:

Frank KOWALEWSKI

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **METHOD FOR TRANSMITTING SIGNALS BETWEEN A FIRST AND A SECOND RADIO STATION, AND RADIO STATION** the specification of which was filed as PCT International Application number PCT/DE 99/03329 on October 16, 1999.

I hereby state that I believe the named inventor or inventors in this Declaration to be the original and first inventor or inventors of the subject matter which is claimed and for which a patent is sought.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365 (b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior foreign application(s): Priority claimed:

| (Number) | (Country) | (Date filed) | Yes | No |
|---|---|---|---|---|
| 198 50 279.6 | GERMANY | OCTOBER 30, 1998 | X | |
| | | | | |

As a named inventor, I hereby appoint the following attorney to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Michael J. Striker, Reg. No. 27233

Direct all telephone calls to Striker, Striker & Stenby at telephone no.: (631) 549 4700 and address and all correspondence to:

STRIKER, STRIKER & STENBY
103 East Neck Road
Huntington, New York 11743
U.S.A.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that wilful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statement may jeopardize the validity of the application or any patent issued thereon.

1W

| Signature: F. Kowalewski | Date: 17.04.01 | Residence and Full Postal Address: Schierke 16 38228 Salzgitter Germany DEX |
|---|---|---|
| Full Name of First or Sole Inventor: Frank KOWALEWKI | Citizenship: GERMAN | |
| Signature: | Date: | Residence and Full Postal Address: |
| Full Name of Second Inventor: | Citizenship: | |
| Signature: | Date: | Residence and Full Postal Address: |
| Full Name of Third Inventor: | Citizenship: | |
| Signature: | Date: | Residence and Full Postal Address: |
| Full Name of Fourth Inventor: | Citizenship: | |
| Signature: | Date: | Residence and Full Postal Address: |
| Full Name of Fifth Inventor: | Citizenship: | |
| Signature: | Date: | Residence and Full Postal Address: |
| Full Name of Sixth Inventor: | Citizenship: | |
| Signature: | Date: | Residence and Full Postal Address: |
| Full Name of Seventh Inventor: | Citizenship: | |
| Signature: | Date: | Residence and Full Postal Address: |
| Full Name of Eighth Inventor: | Citizenship: | |
| Signature: | Date: | Residence and Full Postal Address: |
| Full Name of Ninth Inventor: | Citizenship: | |

| FORM PTO-1390 (Modified) (REV 10-95) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE | ATTORNEY'S DOCKET NUMBER |
|---|---|
| **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371** | 1587 |
| | U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 09/830540 |

| INTERNATIONAL APPLICATION NO. | INTERNATIONAL FILING DATE | PRIORITY DATE CLAIMED |
|---|---|---|
| PCT/DE 99/03329 | OCTOBER 16, 1999 | OCTOBER 30, 1998 |

TITLE OF INVENTION
**METHOD FOR TRANSMITTING SIGNALS BETWEEN A FIRST AND A SECOND RADION STATION, AND RADIO STATION**

APPLICANT(S) FOR DO/EO/US
**Frank KOWALEWSKI**

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ A copy of the International Search Report (PCT/ISA/210).
8. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

**Items 13 to 18 below concern document(s) or information included:**

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
    A **SECOND** or **SUBSEQUENT** preliminary amendment.
16. ☐ A substitute specification.
17. ☐ A change of power of attorney and/or address letter.
18. ☒ Certificate of Mailing by Express Mail
19. ☐ Other items or information:

ET364015805US

JC18 Rec'd PCT/PTO 26 APR 2001

| U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 09/830540 | INTERNATIONAL APPLICATION NO. PCT/DE 99/03329 | ATTORNEY'S DOCKET NUMBER 1587 |
|---|---|---|

20. The following fees are submitted:.

**BASIC NATIONAL FEE ( 37 CFR 1.492 (a) (1) - (5)) :**

| | | CALCULATIONS | PTO USE ONLY |
|---|---|---|---|
| ☐ Search Report has been prepared by the EPO or JPO . . . . . . . . . . . . | **$930.00** | | |
| ☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) . . . . . . . . . . | **$720.00** | | |
| ☐ No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) . . . . . . | **$790.00** | | |
| ☒ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO . . . . . . . . . | **$1,070.00** | | |
| ☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) . . . . . . . . . . | **$98.00** | | |
| **ENTER APPROPRIATE BASIC FEE AMOUNT =** | | **$1,000.00** | |
| Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)). | | **$0.00** | |

| CLAIMS | NUMBER FILED | NUMBER EXTRA | RATE | | |
|---|---|---|---|---|---|
| Total claims | 13 - 20 = | 0 | x $18.00 | **$0.00** | |
| Independent claims | 3 - 3 = | 0 | x $80.00 | **$0.00** | |
| Multiple Dependent Claims **(check if applicable).** | | | ☐ | **$0.00** | |
| **TOTAL OF ABOVE CALCULATIONS =** | | | | **$1,000.00** | |
| Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable).** | | | ☐ | **$0.00** | |
| **SUBTOTAL =** | | | | **$1,000.00** | |
| Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). | | | + | **$0.00** | |
| **TOTAL NATIONAL FEE =** | | | | **$1,000.00** | |
| Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** | | | ☒ | **$40.00** | |
| **TOTAL FEES ENCLOSED =** | | | | **$1,040.00** | |
| | | | | **Amount to be: refunded** | $ |
| | | | | **charged** | $ |

☐ A check in the amount of to cover the above fees is enclosed.

☒ Please charge my Deposit Account No. **19-4675** in the amount of **$1,040.00** to cover the above fees. A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **19-4675** A duplicate copy of this sheet is enclosed.

**NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.**

SEND ALL CORRESPONDENCE TO:

**STRIKER, STRIKER & STENBY**
**103 EAST NECK ROAD**
**HUNTINGTON, NEW YORK 11743**

SIGNATURE

**MICHAEL J. STRIKER**
NAME

**27233**
REGISTRATION NUMBER

**APRIL 26, 2001**
DATE

UNITED STATES PATENT AND TRADEMARK OFFICE

Examiner: Group: Attorney Docket # 1587

Applicant(s) : KOWALEWSKI, F.

Serial No. :

Filed : Simultaneously

For : METHOD FOR TRANSMITTING SIGNALS BETWEEN A FIRST AND A SECOND RADIO STATION, AND A RADIO STATION

SIMULTANEOUS AMENDMENT

April 26, 2001

Honorable Commissioner of Patents and Trademarks
Washington, D.C. 20231

S I R S:

Simultaneously with filing of the above identified application please amend the same as follows:

In the Claims:

Cancel all claims without prejudice.

Substitute the claims attached hereto.

REMARKS:

This Amendment is submitted simultaneously with filing of the above identified application.

With the present Amendment applicant has amended the claims so as to eliminate their multiple dependency.